CHAPTER 9

APPENDICES

APPENDIX 9.1

PHYSICAL AND ENVIRONMENTAL SETTINGS

9.1. Physical and Environmental Settings

9.1.1. Geography and Geology

General Description

The present day Gulf of Mexico is a small ocean basin with a water-surface area of more than one and half million square kilometers. The greatest water depth is approximately 3,700 m. It is almost completely surrounded by land, opening to the Atlantic Ocean through the Straits of Florida and to the Caribbean Sea through the Yucatan Channel. Underlying the present Gulf of Mexico and the adjacent coast is a large geologic basin that began forming during Triassic time (approximately 240 Million years ago (Mya)).

The northern Gulf of Mexico may be divided into several physiographic sub-provinces. In the OCS area, these include: the Texas-Louisiana Shelf, the Texas-Louisiana Slope, the Rio Grande Slope, the Mississippi Fan, the Sigsbee Escarpment, the Sigsbee Plain, the Mississippi-Alabama-Florida Shelf, the Mississippi-Alabama-Florida Slope, the Florida Terrace, the Florida Escarpment, and the Florida Plain. In the Gulf of Mexico, the continental shelf extends seaward from the shoreline to about the 200 m water depth and is characterized by a gentle slope of a few meters per kilometer (less than one degree). The shelf is wide off Florida and Texas, but it is narrower where the Mississippi River delta has extended seawards to near the shelf edge. The continental slope extends from the shelf edge to the Sigsbee and Florida Escarpments, in about 2,000-3,000 m water depth. The topography of the slope is irregular, and characterized by canyons, troughs, and salt structures. The gradient on the slope is normally 1-2 degrees, while the gradient of the Florida Escarpment may reach 45 degrees in some places. The Mississippi Fan has a gentle incline, with slopes of 4 m or less per km with the lower Mississippi Fan having an even flatter slope at 1 m or less per km. The Sigsbee and Florida abyssal plains (ocean floor) are basically horizontal physiographic subprovinces, and are surrounded by features with higher topography.

There are two major sedimentary provinces in the Gulf Coast Region: Cenozoic (the western and central part of the Gulf) and Mesozoic (the eastern Gulf) (Figure 1-1). The Cenozoic Province is a clastic regime, characterized by thick deposits of sand and shale of Paleocene to Recent age (65 Mya to present) underlain by carbonate rocks (limestone, chalk, reefs) of Jurassic and Cretaceous age (205-65 Mya). Approximately 40,000 wells have been drilled in the Western Gulf. The geology has been studied in detail for the identification, exploration, and development of natural gas and oil resources. The Mesozoic Province is a largely carbonate (limestone and reefs) area that extends eastward from the Cretaceous Shelf Edge off the coast of Mississippi, Alabama, and Florida towards the coastline of Florida. Fewer than 350 wells have been drilled in the Mesozoic Province of the Federal offshore, and less is known about the subsurface geology and its natural gas and oil resource potential. Over the last 65 million years, the Cenozoic Era, clastic sediments, (sands, silts, and clays) from the interior North American continent, have entered the Gulf of Mexico basin from the north and west (Apps et al., 1994). The Cenozoic Era is commonly divided into 2 geologic periods – Tertiary and Quaternary. The Tertiary Period (65-1.77 Mya) comprises almost all of the Cenozoic. The most recent part is the Quaternary Period (1.77 Mya-Recent). Geologists also divide the Cenozoic into time periods (Series) of variable duration; from oldest, Paleocene, Eocene, Oligocene, Miocene, Pliocene, Pleistocene, and Holocene. The centers of thick sediment deposition shifted progressively eastward and southward through time in response to changes in the source of sediment supply. In Early Tertiary (65-24 Mya), the Rio Grande River and a system of smaller rivers (Brazos, Colorado, Nuecs, etc.) draining the Texas coastal plain were the main source of sediment supply, resulting in a thick sediment accumulation in the WPA of the Gulf of Mexico. In Late Tertiary (24-1.77 Mya), the center of sediment deposition shifted eastward as the Mississippi River became the major source of sediments entering the Gulf of Mexico. The modern Mississippi River delta complex is the present day reflection of a depositional system that has been periodically shifting positions due to the sediment loading and up-building of the delta since early Miocene time (approximately 24 Mya). Each sedimentary layer is different, reflecting the source of the material, the climate, and the geologic processes occurring during deposition. It is estimated that greater than 15 km of sediments have been deposited locally beneath Texas-Louisiana continental shelf in deep basins.

To produce economically viable accumulations of oil and gas, four things must occur in the geologic setting (petroleum system). First, rocks must contain an enriched supply of organic material capable of forming oil and gas by the chemical and physical changes that occur during burial process (the source). Second, a rock with pores and openings sufficiently connected to hold and transmit oil or gas after it is generated (the reservoir rocks). Third, the layers of rock must be structurally and/or stratigraphically configured so as to capture a large accumulation of hydrocarbon resource (the trap). And fourth, the trapping structure and the reservoir rock must be overlain or configured so that the trap is sealed to prevent the escape of oil or gas (the seal).

Upper Jurassic deposits are considered the major source rocks for gas and oil generation in the Gulf of Mexico. Other source rocks that have been identified in the Gulf of Mexico which may have generated hydrocarbons are as young as Pleistocene (approximately 2 Mya).

Cenozoic Province (Western Gulf)

The Cenozoic Province extends from offshore Texas eastward across the north-central Gulf of Mexico to the edge of the Cretaceous Shelf Edge (commonly called the Florida Escarpment) offshore Mississippi, Alabama and Florida. It incorporates all of the WPA, a large portion of the CPA, and the southwestern portion of the EPA (Figure 1-1). To date, all of the hydrocarbon production on the OCS in the Cenozoic Province is from sands ranging in age from Oligocene to Pleistocene (approximately 34-0.2 Mya).

Two major events laid the template for the structural tectonics and stratigraphy of the Western Gulf: the rifting and drifting of the North American Plate to form the Gulf of Mexico, and the periodic breaching of the land mass to the west, which allowed marine waters into the young basin. The arid climate during the Jurassic inhibited the transport of most clastic materials to the Gulf Basin, allowing for the predominance of carbonate deposition. These two events still influence the depositional patterns of the sediments within the Gulf of Mexico.

Major faulting during the ocean spreading stage created a horst (high block) and graben (low block) system in the Gulf basin that was surrounded by higher more stable land mass (Salvador, 1991). During the Upper Jurassic emergent highs were exposed and subjected to erosion, while adjacent lows filled with sediment. Due to the arid conditions, shallow waters, and the isolated lows formed within the horst and graben system, the eroded sediments were transported only a short distance to the adjacent lows. Repeated flooding and evaporation of the shallow saline waters that filled the basin resulted in a thick, widespread, salt bed (Louann Salt) that was often deposited directly onto basement rocks. Through time the basin cooled, subsided, and was gradually filled with deeper water in which more carbonates (limestone, chalk, reefs) were deposited. At the end of the Mesozoic era, the climate became more temperate which facilitated the erosion of the surrounding mountains. During the last 65 million years (Cenozoic era), several river systems brought the eroded material (clastic) into the Gulf of Mexico.

Because salt is less dense than sand, silt, or clay, it tends to become mobilized as denser sediments are deposited on it. The movement of salt upward pierces overlying rocks and sediment forming structures that have trapped the prolific hydrocarbon resources in the Gulf of Mexico. The updip sediment loading on the shelf and the upward movement of salt during the Tertiary has formed a vast canopy of mobilized salt over most of the outer continental shelf and slope sediments. Individual, isolated salt bodies are called diapirs. Sands in proximity to salt structures have the greatest potential for hydrocarbon accumulation because it is the optimum zone for the successful cross strata migration and accumulation of oil and gas. First, salt structures create pathways for migration of hydrocarbon from Upper Jurassic, Lower Cretaceous, and/or Lower Tertiary source beds to the reservoir sands. Second, thick sands deposited in deltas or in deep sea fans with good porosity (pore space between the sand grains where oil and gas can accumulate) and permeability (connections between the pore spaces through which oil and gas can flow) provide reservoir space. Third, impermeable shales, salt, and/or faults serve as seals for trapping of oil and gas in the pore spaces of the reservoir rocks.

The hydrocarbon-producing horizons on the continental shelf and slope of the Cenozoic Province are mainly Miocene, Pliocene, and Pleistocene, and production generally comes from progressively younger sands in the seaward direction. These Cenozoic productive intervals become thinner and younger with less hydrocarbon potential eastward in the direction of the Cretaceous shelf edge (Mesozoic Province). The Mesozoic section has been penetrated by only a few wells in the Cenozoic Province with no commercial hydrocarbons being identified to date.

Exploration and development in the Gulf of Mexico have resulted in the identification of more than 1,200 fields, of which 1,051 were being developed or producing from the shelf in the Western and Central

Planning Areas. The *2000 Assessment of Conventionally Recoverable Resources of the Gulf of Mexico and Atlantic Outer Continental Shelf as of January 1, 1999* (Lore et al., 2001) has identified sixty-nine plays in the Cenozoic Province; fifty-eight proven, three frontier and eight conceptual plays. As of January 1, 1999, the mean total endowment (reserves plus resources) for these plays is estimated to be 125.190 billion barrel of oil equivalent (BBOE).

Mesozoic Province (Eastern Gulf)

The Mesozoic Province in the OCS extends eastward from the Cretaceous Shelf Edge off the coast of Mississippi, Alabama, and Florida towards the coastline of Florida (Figure 1-1). Although this area has experienced limited drilling and most control points are on the shelf, some general statements can be made concerning resources. This province is dominated by carbonate rocks with some Cenozoic clastic sediments. The geologic age of the sediments above basement rock ranges from the Jurassic to Recent marine sediments at the seafloor. The hydrocarbon potential has been realized throughout the entire geologic interval- from the very shallow, young portion of the Tertiary Pleistocene (1,500-4,000 ft; 450-1,200 m)), to the intermediate Cretaceous James (14,000-16,000 ft; 4,250-4,900 m) and the deep, older Jurassic Norphlet (15,000-24,000 ft; 4,575-7,300 m). Approximately two dozen fields in the Mesozoic Province produce gas from the shallow Cenozoic. In the area offshore of the Florida Panhandle (Pensacola and Destin Dome), a total of 31 wells have been drilled, with 18 of the wells penetrating the Norphlet Formation. The depths at which the Norphlet Formation is found in the Gulf coast region varies from less than 5,000 ft (1,525 m) onshore to more than 24,000 ft (7,300 m) subsea offshore Mississippi and 15,000 ft (4,575 m) subsea in Apalachicola Embayment.

This province has several potential Mesozoic hydrocarbon plays that are downdip equivalents of onshore productive fields. Carbonate rocks often require favorable diagenesis (physical and chemical alterations to the sediments after deposition), faulting, fracturing, and stratigraphy to enhance the low porosity and permeability. The variability of the porosity and permeability within a carbonate rock increases the risk in the determination of potential drainage area, production rates, and resource volume when hydrocarbons are discovered.

To date, the only Mesozoic fields in the OCS are the Jurassic Norphlet (13 fields), the Cretaceous James (4), and the Cretaceous Andrews (1). Most of these fields are located in the northeastern portion of the CPA. The *2000 Assessment of Conventionally Recoverable Resources of the Gulf of Mexico and Atlantic Outer Continental Shelf as of January 1, 1999* (Lore et al., 2001) has identified twenty-three plays in the Mesozoic Province: two proven, five frontier, and sixteen conceptual. As of January 1, 1999, the mean total endowment of these plays is estimated by MMS to be 11.006 BBOE.

Deep Tertiary Gas (Continental Shelf)

The clastic sediments of the Gulf of Mexico are deposited mostly in deltaic environments of sands and shales that are influenced by the location of the sediment source, morphology of the seabed, and the edge of the shelf. Usually the most abundant reservoir rocks are deposited as channel or delta front sands on the shelf. Shifting of the delta complex and ocean currents tend to widely disperse these sands laterally along the shelf. Drilling on the shelf targeted these sands as potential hydrocarbon traps. It was a general belief that on the slope and abyssal fans the sands gradually became less dense and less continuous further from the proximity of the channels. Seismic interpretation (DeVay et al., 2000) and drilling in the deep waters of the Gulf of Mexico over the last 20 years have proven that prolific sands can be deposited in the slope environment and probably on the abyssal plain. In fact, some of the largest fields in the Gulf of Mexico (Thunder Horse (MC 778), Mad Dog (GC 826), Mars (MC 807), Ursa (MC 810), Auger (GB 426), Ram-Powell (VK 956), etc.) have hydrocarbon accumulations in sands deposited in the slope environment (traditionally oil companies name the fields they discover).

The present day shelf was once the slope environment during the Oligocene and Miocene age (approximately 34-7 Mya). The shelf area holds the potential for deepwater delta systems with channels, distributary bars, levees, overbank deposits, and large fan lobes in the older and deeper section. Subsequent faulting and salt movement created traps and supplied conduits for the migration of hydrocarbons. These reservoirs would be subjected to high pressures and temperatures with increasing depth and burial history. Pore pressure increases with depth because of the overburden of the sediments and the amount of water trapped within the sediments. Temperature also increases with depth and can be even higher in areas with less salt intrusions into the sediments. The presence of salt has a cooling effect on the surrounding sediments, causing areas with salt intrusions to have lower temperatures. It is anticipated that these older, deeper reservoirs will be more likely located adjacent to or under the present shelf fields.

Lore et al. (2001) combined the deep Tertiary shelf hydrocarbon potential into two conceptual plays – Lower Tertiary Clastic Gas and Lower Tertiary Clastic Gas and Oil. As of January 1, 1999, the mean total endowment for these two plays is estimated by MMS to be 2.807 BBOE.

Deepwater (Continental Slope and Abyssal Plain)

The continental slope, in the Gulf of Mexico, extends from the shelf edge to approximately 2,000 m water depth. The seafloor gradient on the slope varies from 3-6 degrees to in excess of 20 degrees in some places along escarpments. At the base of the Cenozoic Province slope is an apron of thick sediment accumulation referred to as the continental rise. It gently inclines seaward with slopes of less than one degree, into the abyssal plain (ocean floor).

Bathymetric maps of the continental slope in the northwestern Gulf of Mexico (Bryant et al., 1990; Bouma and Bryant, 1995) reveal the presence of over 105 intraslope basins with relief in excess of 150 m, 28 mounds, and five major and three minor submarine canyons. These intraslope basins occupy much of the area of the continental slope. Intraslope-interlobal and intraslope-supralobal basins occupy the upper and lower continental slope, respectively. Intraslope-interlobal basins are formed by the coalescing of salt canopies, where as supralobal basins are formed by down-warping into a salt sheet.

The middle and lower portions of the Cenozoic Province continental slope contain a canopy of salt, which has moved down-slope in response to sediment loading on the shelf and upper slope. The Sigsbee Escarpment is the southern edge of the canopy within the Gulf of Mexico. The intraslope basins of the slope are essentially Holocene and Pleistocene sediment depocenters. Fewer basins are found on the uppermost continental slope. In general, these basins have lower gradient slopes. The lower continental slope contains eight submarine canyons and the Sigsbee Escarpment, each feature evolving from, in part, the coalescing and migration of salt canopies, an unusual process for the formation of submarine canyons.

The geology and topography of the near-surface continental slope (which is the area of greatest concern with regard to submarine slope stability) offshore Texas and Louisiana result from an interplay between episodes of rapid shelf edge progradation and contemporaneous modification of the sea bed by diapirism and mass-movement processes. Many slope sediments have been uplifted, folded, fractured, and faulted by diapiric action. Between diapirs (topographic highs) were fairways for sand-rich channels. Oversteepening on the basin flanks and resulting mass movements have resulted in the appearance of highly overconsolidated sediments underlying extremely weak pelagic sediments. The construction of the Mississippi Canyon is in part a function of sidewall slumping and pelagic draping of low- shear-strength sediments. In contrast, slope oversteepening and subsequent mass movement have resulted in high pore pressures in rapidly deposited debris flows on the upper slope and on basin floors, resulting in unexpected decreased shear strengths. Biologically generated gas (from microbial activity) and thermally generated gas (from burial maturation) induces the accumulation of hydrates and underconsolidated gassy sediments, which are common on the upper slope. On the middle and lower slope, gassy sediments are uncommon except in basins that do not have a salt base, such as Beaumont Basin; the salt canopy restricts the upward movement of gas from below.

Piston cores are a means to sample the surficial few meters of sediment on the waterbottom. Holocene and Pleistocene piston cores recovered from the continental slope off Texas and Louisiana and from Deep Sea Drilling Project activities indicate the presence of unconsolidated gassy clays, silty clays, sands, and clayey sands, many containing gas hydrates. Most Pleistocene cores recovered on the slope contain hemipelagic (fine-grained) sediments with lesser amounts of turbidites and debris flow material. Holocene sediments on the middle and lower portions of the slope are usually less than a meter thick, but on the upper slope these sediments are found to be several meters thick (Silva et al., 1999).

Water depths over the intraslope intralobal basins located on the middle and lower slope range from 1,500 to 2,200 m. The bathymetry of the upper to middle continental slope area consists of relatively flat ridges and basin floors separated by intraslope escarpments. The intraslope basin escarpments have relief up to 700 m, with slopes generally ranging from 5 to 30 degrees and in some locations up to 50 degrees. Ridges that rim the basins correspond to late, laterally spreading; flat-topped salt tongues overlain by thin sediment cover (Bryant et al., 1992).

The deeper portions of intraslope-intralobal basins are salt free and exhibit a dissected topography consisting of a multitude of small submarine canyons along the walls. Cores taken on the walls of some basins indicate that as much as 3 m of sediment has been removed by slumping. The intraslope-supralobal basin on the lower continental slope, where the physiography is comparatively smooth, shows that relief exists mainly as a rounded depression. The slopes of these basin walls generally range from 4 to 8 degrees, but in some areas are as much as 15 degrees. Basins form on the lower slope where subsidence is due to the evacuation of under-lying salt (i.e., salt withdrawal). This process is particularly evident in basins such as Vaca Basin, where initial basin subsidence appears to have been relatively slow and accompanied by the accumulation of relatively concordant strata (Bryant et al., 1992). A possible scenario for the creation of intraslope supralobal basins is that subsidence of the basin was initially controlled by differential loading caused by lateral variations in sediment thickness while the sediments were still relatively buoyant compared to the salt.

The submarine canyons along the Sigsbee Escarpment (Alaminos, Keathly, Bryant, Cortez, Farnella, and Green Canyons) are the result of the coalescing of salt canopies, the migration of the salt over the abyssal plain, and erosion of the escarpment during periods of low-stand sea level (Bryant et al., 1992). In addition to these large submarine canyons, numerous small submarine canyons and gullies and large slumps occur along the escarpment. Submarine fans of various sizes extend seaward of the canyons onto the continental rise. Slopes along a significant portion of the canyon walls and the escarpment range from 5 to 10 degrees, although slopes in excess of 15 degrees occur.

The major faults on the OCS are extensional faults, referred to as "growth faults," that form contemporaneously with rapid accumulation of massive volumes of sediments. Growth faults are found mostly on the outer shelf and upper slope where sediment accumulation is thickest (Rowan et al., 1999). Faulting resulting from the formation of salt diapirs is the most common type of faulting on the upper slope. On the middle and lower continental slope, faulting related to salt-stock and salt canopies is the most common type of faulting. Extensive faulting is present on the rim of most intraslope-intralobal and supralobal basins on the middle and lower continental slope. These faults are extensional faults caused by the upward movement of salt resulting from pressures created by sediment accumulation within basins. This type of faulting results in the occurrence of a large number of small faults in the area of the seafloor undergoing extension. In some areas of the slope, the upward migration of salt results in the seafloor being extensively fractured (i.e., faulted) and continuously displaced.

Portions of some of the submarine canyons (e.g., Bryant Canyon) are being filled with salt. Turbidity current flows that are active during times of low-stand sea level create the canyons. Subsequently, sediments that accumulate on the margins of the canyon create a differential loading on the salt causing the salt to migrate into the canyon. The migration of salt into the canyon can occur at a rate of centimeters per year. On the middle and lower continental slope, salt may occur very close to the seafloor. For example, on the salt plug called "Green Knoll," salt is exposed at the seafloor and is being dissolved by seawater, resulting in the collapse of the cap of the knoll. In the intraslope-intralobal Orca Basin, salt is exposed at the bottom of the northern portion of the basin forming a famous brine pool.

The *Outer Continental Shelf Petroleum Assessment 2000* (USDOI, MMS, 2001) estimates the total endowment of the deepwater (200-2,400 m water depth) to be 63.214 BBOE. The most prolific play in the deepwater continental slope is identified to be the deposits of slope-fan-environment ranging in age from Oligocene to Pleistocene. The total endowment of the abyssal plain (greater than 2,400 m water depth) is estimated by MMS to be 8.166 BBOE with the major play being the Foldbelt ranging in age from Jurassic to Miocene.

Geologic Hazards

The seafloor geology of the Gulf of Mexico reflects the interplay between episodes of diapirism, mass sediment movement, and sea-level fluctuations. Geologic features on most of the continental shelf (shoreline to about 200-m water depth) are simple and uniform. The main hazards in this area are faulting, shallow-gas pockets, and buried channels. Deepwater regions in the Gulf of Mexico have complex regional salt movement, both horizontal and vertical, which makes it a unique ocean basin. This movement greatly alters the seafloor topography forming sediment uplifts, mini-basins, and canyons. Salt moves horizontally like a glacier and can be extruded to form salt tongues, pillows, and canopies below an ever-increasing weight of sediment. Vertical salt forms range from symmetric bulb-shaped stocks to walls. While salt creates traps that are essential to petroleum accumulation, salt movement can cause potential hazards such as seafloor fault scarps, slumping from steep unstable slopes, shallow gas pockets, seeps and vents, and rocky or hard bottom areas.

Gas hydrates (gas trapped in ice crystals) have been found in the Gulf of Mexico in localized deepwater areas of very cold temperature and high pressure at or near the seafloor. Gas hydrates can rapidly dissociate when heated or otherwise disturbed (for example, by an anchor) and cause sediment instability. Although the Gulf of Mexico has had no drilling incident associated with hydrates, they are a problem in other parts of the world.

The Mississippi River delta presents a unique set of geologic hazards because of high sedimentation rates, which cause very unconsolidated, high-water-content, and low-strength sediments. Under these conditions, the sediments can be unstable, and slope failure or mass transport of sediments can result. These failures can be triggered by cyclic leading associated with hurricanes, overloading or oversteepening of the slope sediments, or uplift associated with movement of salt. These failures can form mudflow gullies, overlapping mudflow lobes, collapse depressions, slumps, and slides. Small, buried, river channels can result in differential sediment compaction and pose a hazard to jackup rigs.

Over-pressure conditions in sedimentary section can result from loading by rapid deposition, sand collapse, in-leaking gas, or salt tectonics. Drilling through an over-pressured shallow-gas pocket can cause loss of mud circulation or a blowout (a blowout occurs when improperly balanced well pressure results in sudden uncontrolled release of fluids from a well bore or well head). A shallow water flow can cause similar drilling problems. Over-pressured conditions can develop in deepwater when a “water sand” is trapped by a shale seal. Over-pressured formation water may escape around or through the wellbore to the seafloor and wash out the well foundation. No shallow water flow event in the Gulf of Mexico has resulted in an oil spill.

Deep drilling may encounter abnormally high geopressures. Deep drilling may also encounter hydrogen sulfide, which can occur near salt domes overlain by caprock and is the product of sulfate reducing microbes.

Potential Mitigation Measures

The best mitigation for most hazards is avoidance after detection by a geophysical survey. Leaseholders are required to run geophysical surveys before drilling in order to locate potential geologic or man-made hazards (CFR 250.203). In deepwater, most companies do a remotely operated vehicle (ROV) inspection of the seafloor for a pre-spud location. Companies are also required to take and analyze sediment borings for platform sites. Areas of hydrogen sulfide occurrences can be predicted and sensors installed on drilling rigs to warn operators. Certain leases also require archaeological surveys and live-bottom surveys to protect sensitive areas. Every application for permit to drill a well in the Gulf of Mexico is reviewed by MMS geologists, geophysicists, and engineers to ensure compliance with standard drilling practices and MMS regulations. All rigs and platforms are inspected by the MMS on a regular basis to ensure all equipment and procedures comply with Federal regulations for safety and environmental protection.

Geologic Condition	Hazard	Mitigations
Fault	Bend/shear casing Lost circulation Gas conduit	Stronger casing/heavier cement
Shallow Gas	Lost circulation Blowout Crater	Kill mud Pilot hole Circulate mud/drill slower Blow-out preventer/diverter Pressure while drilling log
Buried Channel	Jack-up leg punch through	Pre-load rig Mat support All rig legs in same type of sediment
Slump	Bend/shear casing	Thicker casing Coil/flexible pipeline
Water Flow	Erosion/washout Lost circulation	Kill mud, foam cement Pilot hole Pressure while drilling

9.1.2. Physical Oceanography

The Gulf of Mexico is a semi-enclosed, subtropical sea with an area of approximately 1.5 million km^2. The main physiographic regions of the Gulf Basin are the continental shelf (including the Campeche, Mexican, and U.S. shelves), continental slopes and associated canyons, abyssal plains, the Yucatan Channel, and Florida Straits. The continental shelf width along the U.S. coastline is about 16 km off the Mississippi River, and 156 km off Galveston, Texas, decreasing to 88 km off Port Isabel near the Mexican border. The depth of the central abyss ranges to approximately 3,700 m. The water volume of the entire Gulf, assuming a mean water depth of 2 km, is 2 million km^3. The water volume of the continental shelf, assuming a mean water depth of 50 m, is 25,000 km^3.

The Loop Current, the dominant circulation feature in the Gulf, enters through the Yucatan Channel and exits through the Florida Straits. The sill depth at the Florida Straits is about 800 m; the effective sill depth at the Yucatan Channel is about 1,820 m (Sturges et al., 1993). Water masses in the Atlantic Ocean and Caribbean Sea that occur at greater depths cannot enter the Gulf of Mexico. The Loop Current is a part of the western boundary current system of the North Atlantic. This is the principal current and source of energy for the circulation in the Gulf. The Loop Current has a mean area of 142,000 km^2 (Hamilton et al., 2000). It may be confined to the southeastern Gulf of Mexico or it may extend well into the northeastern or north-central Gulf, with intrusions of Loop Current water even to the shelf edge along Louisiana and the Florida Panhandle (e.g., Huh, 1981; Paluszkiewicz, 1983).

Closed rings of clockwise-rotating (anticyclonic) water, called Loop Current Eddies (LCE's), separate periodically from the Loop Current. Studies on the frequency of Loop Current intrusions into the eastern Gulf and the frequency of LCE separation (Sturges, 1992 and 1994; Sturges et al., 1993; Vukovich, 1988 and 1995) clearly show these to be chaotic processes. Currents associated with the Loop Current and its eddies extend to at least depths of 800 m, the sill depth of the Florida Straits, and geostrophic shear is observed to extend to the sill depth of the Yucatan Channel. These features may have surface speeds of 150-200 cm/s or more; speeds of 10 cm/s are not uncommon at a depth of 500 m (Cooper et al., 1990). Near the bottom of the Loop Current, velocities are low and fairly uniform in the vertical although with bottom intensification, a characteristic of topographic Rossby waves (TRW's). This indicates that the Loop Current is in fact a source of the TRW's, which are a major component of deep circulation below 1,000 m in this part of the Gulf (Sturges et al., 1993; SAIC, 1989; Hamilton, 1990). Anticyclonic eddies separate from the Loop Current from 4 to 16 months apart, with frequencies peaked at 8-9 months and at 13-14 months (Sturges, 1994). These Loop Current eddies are also called warm-core eddies, since they surround a central core of warm Loop Current water. These eddies can have surface speeds of 150-200 cm/s or more; speeds of 10 cm/s are not uncommon at 500 m (Cooper et al., 1990). Although the Loop Current and LCE's have been studied since the early 1960's, details of their velocity distributions and variability remain virtually unknown. Only a few estimates of three-dimensional velocity fields have been reported (e.g., Cooper et al., 1990; Forristall et al., 1992). The Sturges et al. (1993) model suggests a surprisingly complex circulation pattern beneath these anticyclones, with vortex-like and wave-like features that interact with the bottom topography (Welsh and Inoue, 2000). These model findings are consistent with Hamilton's (1990) interpretation of observations. Warm-core eddies can have lifespans of one year or more (Elliot, 1982). Therefore, their effects can persist at one location for long periods – weeks or even months (e.g., Nowlin et al., 1998). The average diameter of warm-core eddies is about 200 km, and they may be as large as 400 km in diameter. Initially, these features have diameters greater than 250 km, with typical values closer to 350 km, which decrease by 45 percent within 150 days and by 70 percent within 300 days (Elliot, 1982). After separation from the Loop Current, these eddies often translate westward across the Gulf of Mexico at a speed of about 5 km/day (range 1-20 km/day), and interact with other eddies or with continental margins in the western Gulf, generating secondary cyclones and anticyclones (SAIC, 1988). They have typical lifetimes of 350-400 days (Elliott, 1982) and decay by interactions with boundaries, ring shedding, and ring-ring interactions. The net result is that at almost any given time, the Gulf is populated with numerous eddies, which are interacting with one another and with the margins. Warm eddy water is present over only 15 percent or less of the approximately 1.5 million km^2 total surface area of the Gulf of Mexico (SAIC, 1989).

Cold-core cyclonic (counter-clockwise rotating) eddies have been observed in the study region as well, and surface waters within these cyclones are cooler and fresher than adjacent waters. Cyclonic circulation is associated with upwelling, which brings cooler, deeper water towards the surface. Small cyclonic eddies around 50-100 km in diameter have been observed over the continental slope off Louisiana (Hamilton, 1992). These eddies can persist for six months or longer and are relatively stationary. Very little published information is available concerning the velocity fields within cyclonic and ancillary anticyclonic eddies, though a few reports exist (e.g., Hamilton, 1992; Forristall et al., 1992). Hamilton (1992) reports the existence in the central Gulf and over the Louisiana continental shelf of cold cyclones with strong temperature gradient to a depth of 800 m (upper layer currents of 30-50 cm/s), little surface temperature expression, diameters of 100-150 km, and long lifetimes.

Energetic, high-frequency currents have been observed when LCE's flow past structures, but they are not well documented. Such currents would be of concern to offshore operators because they could induce structural fatigue of materials.

Current meters at depths of up to 3,175 m have directly measured abyssal currents in the Gulf of Mexico. The major low-frequency fluctuations in velocity of these currents in the bottom 1,000-2,000 m of the water column have the characteristics of TRW's. These long waves have wavelengths of 150-250 km, periods greater than ten days, and group velocities estimated at 9 km/day. They are characterized by columnar motions that are intensified near the seafloor. They move westward at higher group velocities than the translation velocity of 3-6 km/day that is typical of anticyclonic eddies. The Loop Current and LCE's are thought to be major sources of these westward propagating TRW's (Hamilton, 1990).

In general, past observations of currents in the deepwater Gulf of Mexico have revealed decreases in current speed with depth. During late 1999, a limited number of high-speed current events, at times approaching 2 kn, were observed at depths exceeding 1,500 m in the northern Gulf of Mexico (Hamilton and Lugo-Fernandez, 2001). Furrows on the seafloor, apparently resulting from the erosional effects of high-speed currents, have also been discovered in the northern Gulf.

In deepwater, several oil and gas operators have observed very high-speed currents in the upper portions of the water column. These high-speed currents can last as long as a day. Such currents may have vertical extents of less than 100 m, and they generally occur within the depth range of 100-300 m in total water depths of 700 m or less over the upper continental slope. Maximum speeds exceeding 150 cm/s have been reported. The higher-speed currents appear to propagate upward, characteristic of baroclinic waves (either sub- or super-inertial). It seems possible that such phenomena could be intensified near topographic irregularities and slopes. The mechanisms by which these currents are generated are unknown and presently under investigation.

A general circulation pattern that most closely approximates the time-averaged, or background, circulation for the Gulf of Mexico has been constructed from the limited available hydrography and will be described below. Few hydrographic surveys of the entire Gulf of Mexico have been conducted during the past several decades. Examples of data sources from which similar resulting patterns result include a series of cruises in the 1960's (e.g., the *R/V Hidalgo* 62-H-3 cruise, and the *R/V Geronimo* and *R/V Kane* cruises). The general circulation pattern based on the *R/V Hidalgo* cruise completed in 1962 is illustrated in Figure 9-1 (after Nowlin, 1972). The contours in Figure 9-1 represent the flow paths (streamlines) of the geostrophic surface currents calculated relative to the 1,000-m reference surface. These currents reflect the medium- to large-scale distributions of temperature and salinity, and thus density. This pattern also is characteristic of time-averaged outputs from numerical models of the circulation in the Gulf (e.g., see Hurlbert and Thompson, 1980 and 1982).

The major large-scale permanent circulation feature present in the Western and Central Gulf of Mexico is an anticyclonic (clockwise-rotating) feature oriented about ENE-WSW with its western extent near lat. 24° N. off Mexico. There has been debate regarding the mechanism for this anticyclonic circulation and the possible associated western boundary current along the coast of Mexico. Elliott (1979) attributed LCE's as the primary source of energy for the feature, but Sturges (1993) argued that wind stress curl over the western Gulf is adequate to drive an anticyclonic circulation with a western boundary current. Sturges (1993) found annual variability in the wind stress curl corresponding to the strongest observed boundary current in July and the weakest in October. Based on ship-drift data, Sturges (1993) showed the maximum northward surface speeds in the western boundary current were 25-30 cm/s in July and about 5 cm/s in October; the northward transport was estimated to vary from 2.5 to 7.5 m^3/s. He reasoned that the contribution of LCE's to driving this anticyclonic feature must be relatively small. Others have attributed the presence of a northward flow along the western Gulf boundary to ring-slope-ring interactions (Vidal et al., 1999).

Perhaps the currents of greatest concern are those resulting from strong, episodic wind events such as tropical cyclones (especially hurricanes), extratropical cyclones, and cold-air outbreaks. Such wind events can result in extreme waves and cause currents with speeds of 100-150 cm/s over the continental shelves. Recent examples for the Texas-Louisiana shelf and upper slope are given in Nowlin et al. (1998). Other researchers (e.g., Brooks, 1983 and 1984) have measured the effects of such phenomena down to depths of 700 m over the continental slope in the northwestern Gulf.

Cold fronts, as well as diurnal and seasonal cycles of heat flux at the air/sea interface, affect near-surface water temperatures, although water at depths greater than about 100 m remains unaffected by surface boundary heat flux. Water temperature is greater than air temperature at the air/sea interface during all seasons. Frontal passages over the region can cause changes in temperature and velocity structure in the upper layers, specifically increasing current speeds and variability. These fronts tend occur with frequencies from 3-10 days (weatherband frequency). In the winter, the shelf water is nearly homogeneous due to wind stirring and cooling by fronts and winter storms.

Tropical conditions normally prevail over the Gulf from May or June until October or November. Hurricanes increase surface current speeds to 100-150 cm/s over the continental shelves, and cool the surface waters in much the same way as do cold fronts, but may stir the mixed layer to an even greater depth. Brooks (1983 and 1984) has measured the effects of hurricanes down to depths of 700 m over continental slopes in the northwestern Gulf. Hurricane Allen affected currents on the Texas slope in early August 1980. A strong southward, alongshore current occurred with the landward passage of this hurricane, exceeding 90 cm/s at 200 m and 15 cm/s at 700 m, triggering a series of internal waves with near inertial period. Surface waves and sea state may limit normal oil and gas operations as well as oil-spill response activities (Brower et al., 1972).

From October or November until March or April, the Gulf experiences intrusions of cold, dry continental air masses. During passage of a cold front, the cold-air mass is warmed as it travels over surface waters. In deeper waters, the mixed layer deepens. In the summer, vertical density stratification increases with the development of a seasonal thermocline. The transition between summer and winter is believed to occur with passage of the first cold front, and the transition from winter to summer coincides with the last cold front (Molinari and Festa, 1978). The formation of extratropical cyclones and cold-air outbreaks can both cause highly energetic surface currents. On March 12, 1993, a Class 5 extratropical cyclone moved from west to east across the Texas-Louisiana shelf with its center approximately over the 1,500-m isobath. Initially, the flow over the outer shelf and slope was toward the northeast as part of an induced cyclonic circulation over the Texas-Louisiana shelf. Following the passage of the storm out of the area on 13 March, a surge occurred to the southwest, followed by a period (14-17 March) of strong motion toward the northeast, with diurnal modulation. This was followed by an energetic near-inertial oscillation with decreasing amplitude lasting over a week. Speeds as high as 67 cm/s at 10 m and 35 cm/s at 190 m were observed.

During the MMS-sponsored Texas-Louisiana Shelf Circulation and Transport Process (LATEX) program of the early 1990's, a class of energetic surface currents previously unreported in the Gulf of Mexico were found over the Texas and Louisiana shelves (Nowlin et al., 1998). July 1992 observations in 200 m water offshore of Louisiana were of maximum amplitudes of 40-60 cm/s at a depth of 12 m during conditions of light winds. The period of diminished amplitudes followed an atmospheric frontal passage. These are near-circular, clockwise-rotating oscillations with a period near 24 hours. They seem to be an illustration of thermally induced cycling (DiMarco et al., 2000) in which high-amplitude rotary currents can exist in thin mixed layers typical of summer. By contrast, December 1992 measurements evidence no such behavior. Many examples of such currents, in phase at distinct locations, exist for the Texas-Louisiana shelf and, by implication, further offshore. Currents at a depth of 1 m have been observed to reach 100 cm/s.

Clearly episodic wind events can cause major currents in the deep waters of the Gulf. The initial currents give rise to inertial oscillations with decreasing amplitudes, which last for up to about 10 days and are superimposed on longer period signals.

During the mid-1980s, barotropic (i.e., depth independent) currents were observed to extend from depths near 1,000 m to the bottom. Hamilton (1990) concluded that such currents result from topographic Rossby waves triggered by the Loop Current, perhaps on separation of LCE's. Propagation speeds for these currents found into the western Gulf are higher (perhaps 9 km/day) than the average propagation speeds (5 km/day) of the separated LCE's. Sturges et al. (1993) observed similar phenomena from numerical model results for the Gulf. Deep circulation patterns distinct from those associated with the surface-intensified eddies also were seen in numerical model studies by Inoue and Welsh (1997). Proprietary oil-company measurements have indicated such barotropic currents with maximum speeds near 40 cm/s and periods of weeks. Moreover, data give some indication of current intensification near the bottom. This class of barotropic currents, with possible bottom intensification, is of high interest to offshore operators attempting oil and gas production in water depths of 1,000 m and greater; measurements in the CPA and WPA are ongoing by MMS and offshore operators.

Furrows oriented nearly along depth contours have been observed recently in the region of long. 90° W. just off the Sigsbee Escarpment and near the Bryant Fan, south of Bryant Canyon, from long. 91° W. to 92.5° W. Depths in those regions range from 2,000 to 3,000 m. Speculation based partly on laboratory experimentation is that near-bottom speeds of currents responsible for the furrows that are closest to shore might be 50 cm/s, and possibly in excess of 100 cm/s, and these currents may be oriented along isobaths and increase in strength toward the escarpment. These currents might be sporadic or quasi-permanent.

Continental shelf waves may propagate westward and southward along the slope in the central and western Gulf of Mexico. These are long waves similar to TRW's, but their energy is concentrated along a sloping bottom with shallow water to the right of the direction of propagation, and due to this constraint they are effectively "trapped" by the sloping bottom topography. Cold water from deeper off-shelf regions moves onto and off of the continental shelf by cross-shelf flow associated with upwelling and downwelling processes.

Inner-shelf currents on the Louisiana-Texas continental shelf flow in the downcoast (south or west) direction during non-summer months, reversing to upcoast flow in the summer (Cochrane and Kelly, 1986; Nowlin et al., 1998). Modeling results show that the spring and fall reversals in alongshore flow can be accounted for by local wind stress alone (Current, 1996). Monthly averaged alongshore currents on the outer shelf are upcoast in the mean, but showed no coherent pattern in the annual signal and were not often in the same alongshore direction at different outer-shelf locations (Nowlin et al., 1998). Mean cross-shelf geostrophic transport observed at the Louisiana-Texas shelf break was offshore during the winter (particularly in the upper 70 m of the water column), and onshore during the summer (Current and Wiseman, 2000).

Historical hydrographic cruises include several surveys of the entire Gulf of Mexico in the 1960's (including *R.V. Hidalgo* 62-H-3, *R.V. Geronimo* 67-G-12 and *R.V. Geronimo* 67-G-16) from which nearly synoptic circulation for the entire Gulf can be inferred. In addition to these synoptic cruises, a number of hydrographic cruises of more limited scope were carried out in the northeast Gulf of Mexico and surrounding regions aboard the *R.V. Alaminos,* the *R.V. Gyre,* and other research vessels.

Table 9-1 gives the names, depth ranges, densities, and identifying features of the remnants of the principal water masses. This table excludes the highly variable surface waters observed in 1) the eastern Gulf of Mexico by Morrison and Nowlin (1977) and Nowlin and McLellan (1967); and 2) the western

Gulf of Mexico by Morrison et al. (1983) and Nowlin and McLellan (1967). Water mass property extremes are closely associated with specific density surfaces. All of these subsurface waters derive from outside the Gulf and enter from the Caribbean Sea through the Yucatan Channel. Below about 1,800 m, horizontal distributions of temperature and salinity within the Gulf are essentially uniform. All of these subsurface waters flow into the Gulf from the Caribbean Sea through the Yucatan Channel. Based on historical observations, horizontal distributions of temperature and salinity within the Gulf are thought to be relatively uniform below the effective sill depth of the Yucatan Channel.

Summer heating and stratification affect continental-shelf waters in the Gulf of Mexico. Salinity is generally lower nearshore, although fresh water from the Mississippi and other rivers occasionally moves into outer shelf waters. Freshwater intrusions further lower the salinity after local storms.

Figure 9-2 presents composite plots of temperature vs. salinity, temperature vs. depth, and salinity vs. depth for the winter cruise 62-H-3 that covered the entire Gulf. Evident in these plots is the wide range of near-surface values, especially because sampling extended over the shelves.

Figure 9-3 better illustrates upper-layer waters with two different distributions. Caribbean-type water with a high maximum salinity marking the core of the Subtropical Underwater is found within the region enclosed by the Loop Current and LCE's, illustrated in the figure by station 215. This station was within an older LCE found in the northwestern Gulf. The second type of distribution is illustrated in the figure by station 165, which was located within a cyclone in the northwestern Gulf. At that station 165, the salinity maximum at the Subtropical Underwater core is much reduced by vertical mixing (characteristic of open Gulf waters outside of the Loop Current and of LCE's), and temperatures and salinities are found higher in the water column than within the LCE's. Robinson (1973) describes the seasonal variability of the upper waters of the Gulf in terms of the monthly mean temperatures of the surface and upper 150 m and the depth to the top of the thermocline. Contoured fields of temperature at six levels and the depth of the thermocline are presented. Also shown are time series of temperatures averaged for each 2.5^{o} by 2.5^{o} square.

9.1.3. Meteorological Conditions

General Description

The Gulf of Mexico is influenced by a maritime subtropical climate controlled mainly by the clockwise circulation around the semipermanent area of high barometric pressure commonly known as the Bermuda High. The Gulf of Mexico is located to the southwest of this center of circulation. This proximity to the high-pressure system results in a predominantly southeasterly flow in the Gulf of Mexico region. Two important classes of cyclonic storms are occasionally superimposed on this circulation pattern. During the winter months, December through March, cold fronts associated with cold continental air masses influence mainly the northern coastal areas of the Gulf of Mexico. Behind the fronts, strong north winds bring drier air into the region. Tropical cyclones may develop or migrate into the Gulf of Mexico during the warmer months. These storms may affect any area of the Gulf of Mexico and substantially alter the local wind circulation around them. In coastal areas, the sea breeze effect may become the primary circulation feature during the summer months of May through October. In general, however, the subtropical maritime climate is the dominant feature in driving all aspects of the weather in this region; as a result, the climate shows very little diurnal or seasonal variation.

Selected climatological data for a few selected Gulf coastal locations can be found in Table 9-2.

Pressure, Temperature, and Relative Humidity

The western extension of the Bermuda High dominates the circulation throughout the year, weakening in the winter and strengthening in the summer. The average monthly pressure shows a west to east gradient along the northern Gulf during the summer. In the winter, the monthly pressure is more uniform along the northern Gulf. The minimum average monthly pressure occurs during the summer. The maximum pressure occurs during the winter as a result of the presence and influence of transitional continental cold air.

Average air temperatures at coastal locations vary with latitude and exposure. Air temperature ranges from highs in the summer of 24.7-28.0 ^{o}C to lows in the winter of 2.1-21.7 ^{o}C. Winter temperatures depend on the frequency and intensity of penetration by polar air masses from the north. Air temperatures over the open Gulf exhibit narrower limits of variations on a daily and seasonal basis due to the moderating effect of the large bodies of water. The average temperature over the center of the Gulf is about 29 °C in the summer and between 17 and 23 °C in the winter.

The relative humidity over the Gulf is high throughout the year. Minimum humidities occur during the late fall and winter when cold, continental air masses bring dry air into the northern Gulf. Maximum humidities occur during the spring and summer when prevailing southerly winds bring in warm, moist air. The climate in the southwestern Gulf of Mexico is relative dry.

Surface Winds

Winds are more variable near the coast than over open waters because coastal winds are more directly influenced by the moving cyclonic storms that are characteristic of the continent and because of the land and sea breeze regime. During the relatively constant summer conditions, the southerly position of the Bermuda High generates predominantly southeasterly winds, which become more southerly in the northern Gulf. Winter winds usually blow from easterly directions with fewer southerlies but more northerlies.

Precipitation and Visibility

Precipitation is frequent and abundant throughout the year but does show distinct seasonal variation. Stations along the entire coast record the highest precipitation values during the warmer months of the year. The warmer months usually have convective cloud systems that produce showers and thunderstorms; however, these thunderstorms rarely cause any damage or have attendant hail (USDOC, 1967; Brower et al., 1972). The month of maximum rainfall for most locations is July. Winter rains are associated with the frequent passage of frontal systems through the area. Rainfalls are generally slow, steady, and relatively continuous, often lasting several days. Snowfalls are rare, and when frozen precipitation does occur, it usually melts on contact with the ground. Incidence of frozen precipitation decreases with distance offshore and rapidly reaches zero.

Warm, moist Gulf air blowing slowly over chilled land or water surfaces brings about the formation of fog. Fog occurrence decreases seaward, but visibility has been less than 800 m due to offshore fog. Coastal fogs generally last 3-4 hours, although particularly dense sea fogs may persist for several days. The poorest visibility conditions occur during winter and early spring. The period from November through April has the lowest visibility. Industrial pollution and agricultural burning also impact visibilities.

Mixing Height and Atmospheric Stability

The mixing height is very important because it determines the volume available for dispersing pollutants. Because the mixing height is directly related to vertical mixing in the atmosphere, a mixed layer is expected to occur under neutral and unstable atmospheric conditions. The mixing height tends to be lower in winter, and daily changes are smaller than in summer.

Severe Storms

The Gulf of Mexico is part of the Atlantic tropical cyclone basin. Tropical cyclones generally occur in summer and fall seasons; however, the Gulf also experiences winter storms or extratropical storms. These winter storms generally originate in middle and high latitudes and have winds that can attain speeds of 15-26 m/sec (11.2-58.2 mph). The Gulf is an area of cyclone development during cooler months due to the contrast of the warm air over the Gulf and the cold continental air over North America. Cyclogenesis, or the formation of extratropical cyclones, in the Gulf of Mexico is associated with frontal overrunning (Hsu, 1992). The most severe extratropical storms in the Gulf originate when a cold front encounters the subtropical jetstream over the warm waters of the Gulf. Statistics of 100-year data of extratropical cyclones reveal that most activity occurs above 25°N. latitude in the Western Gulf of Mexico. The mean number of these storms ranges from 0.9 near the southern tip of Florida to 4.2 over central Louisiana (USDOI, MMS, 1988).

The frequency of cold fronts in the Gulf exhibits similar patterns during the four-month period of December through March. During this time the area of frontal influence reaches 10° N. latitude. Frontal frequency is about nine fronts per month (1 front every 3 days on the average) in February and about seven fronts per month in March (1 front every 4-5 days on the average). By May, the frequency decreases to about four fronts per month (1 front every 7-8 days) and the region of frontal influence retreats to about 15° N. latitude. During June-August frontal activity decreases to almost zero and fronts seldom reach below 25° N. latitude (USDOI, MMS, 1988).

Tropical cyclones affecting the Gulf originate over the equatorial portions of the Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. Tropical cyclones occur most frequently between June and November. Based on 42 years of data, there are about 9.9 storms per year with about 5.5 of those becoming major hurricanes in the Atlantic Ocean (Gray, written communication, 1992). Data from 1886 to 1986 show that 44.5 percent of these storms, or 3.7 storms per year, will affect the Gulf of Mexico (USDOI, MMS, 1988). The Yucatan Channel is the main entrance of Atlantic storms into the Gulf of Mexico, and a reduced translation speed over Gulf waters leads to longer residence times in this basin.

There is a high probability that tropical storms will cause damage to physical, economic, biological, and social systems in the Gulf. Tropical storms also affect OCS operations and activities; platform design needs to consider the storm surge, waves, and currents generated by tropical storms. Most of the damage is caused by storm surge, waves, and high winds. Storm surge depends on local factors, such as bottom topography and coastline configuration, and storm intensity. Water depth and storm intensity control wave height during hurricane conditions. Sustained winds for major hurricanes (Saffir-Simpson Category 3 and above) are higher than 49 m/sec (109.6 mph). The Saffir-Simpson scale definitions and a listing of the most damaging hurricanes in the Gulf can be found in Table 9-3.

9.1.4. Artificial-Reefs and Rigs-to-Reefs Development

Artificial-Reef Development

Artificial reefs have been used along the coastline of the United States since the early nineteenth century. Stone (1974) documented that the use of obsolete materials to create artificial reefs has provided valuable habitat for numerous species of fish in areas devoid of natural hard bottom. Stone et al. (1979) found reefs in marine waters not only attract fish, but in some instances also enhance the production of fish.

The long-standing debate as to whether artificial reefs contribute to biological production or merely attract the associated marine resources still continues within the scientific arena. While no unified answer to this dichotomy persist among the artificial-reef researchers, the generally accepted conclusion is that artificial reefs both attract and produce fish. This conclusion depends on a variety of factors, such as associated species, limiting environmental factors, fishing pressure, and type of materials used. The degree to which any of the above factors can be controlled will dictate whether any particular artificial reef attract fish or produce fish. In reality, many artificial reefs probably do both attract and produce fish at the same time.

The U.S. Congress recognizing the social and economic value in developing artificial reefs passed the National Fishing Enhancement Act (NFEA) in 1984. The NFEA called for the development of a national plan to provide guidance to those individuals, organizations, and agencies interested in artificial reef development and management. The NFEA directed the Secretary of Commerce to develop and publish a long-term National Artificial Reef Plan (NARP) to promote and facilitate responsible and effective use of artificial reefs using the best scientific information available. In 1985, the National Marine Fisheries Service (NMFS) wrote and completed the NARP. The NARP states that properly designed, constructed, and located artificial reefs can enhance the habitat and diversity of fishery resources; enhance United States recreational and commercial fishing opportunities; increase the energy efficiency of recreational and commercial fisheries; and contribute to the United States coastal economies.

The NARP provides general criteria for selection of materials for artificial-reef applications. These criteria include: (1) function, which is related to how well a material functions as reef habitat; (2) compatibility, which is related to how compatible a material is with the environment; (3) durability, which is related to how long a material will last in the environment; (4) stability, which is related to how stable a material will be when subject to storms, tides, currents, and other external forces, and (5) availability, which is related to how available a material is to an artificial-reef program.

One of the most significant recommendations in the NARP was to encourage the development of State-specific artificial-reef plans. The Gulf States Marine Fisheries Commission (GSMFC) and Atlantic States Marine Fisheries Commission (ASMFC) began to coordinate State artificial-reef program activities for States along the coast of the Gulf of Mexico and Atlantic Ocean respectively. Most of the States along the Gulf and Atlantic coasts have taken a leadership role in artificial-reef development and management, having developed state-specific plans, and established protocols for siting, deployment, and evaluation of materials for artificial reefs. Each commission formed working committees comprised of State artificial-reef program personnel, and representatives from appropriated Federal agencies, including the MMS. Artificial Reef Working Committees, of the GSMFC and ASMFC, meet jointly to discuss artificial-reef issues of a national scope, and separately to discuss issues specific to the Gulf and Atlantic perspective. As a result, these committees have been influential in shaping regional and national artificial-reef policies and effecting future positive program changes within State and Federal agencies. The working committees have developed guidelines for marine artificial-reef materials. The guidelines provide State and Federal agencies and the general public information related to the history, identification of the benefits, drawbacks, and limitations, and use of selected materials for use in the development of marine artificial reefs. The working committees have also produced the document titled "Coastal Artificial Reef Planning Guide." The document reflects the working committee's recommendations to the NMFS for revisions to the National Artificial Reef Plan.

State Artificial Reef Programs and Plans

All of the five Gulf of Mexico coastal States – Texas, Louisiana, Mississippi, Alabama, and Florida – have artificial-reef programs and plans. The following are brief descriptions of each State's artificial-reef program. The States' artificial-reef planning areas, general permit areas, and permitted artificial-reef sites within the area of influence considered in this EIS are shown on Figure 9-4.

Texas

In 1989, the Texas State legislature passed the State's Artificial Reef Act. The Act provided guidance for planning and developing artificial reefs in a cost-effective manner to minimize conflicts and risk to the environment. The Act also directed the Texas Parks and Wildlife Department to promote, develop, maintain, monitor, and enhance the artificial-reef potential in State waters and Federal waters adjacent to Texas. The Act defined an artificial reef as a structure constructed, placed, or permitted in the navigable water of Texas or water of the Federal exclusive economic zone adjacent to Texas for the purpose of enhancing fishery resources and commercial and recreational fishing opportunities. To fulfill these purposes, the Department was directed to develop a State artificial-reef plan in accordance with Chapter 89 of the Texas Parks and Wildlife code. Texas artificial reefs are mostly retired oil and gas platforms, liberty ships, and military hardware (battle tanks and armored vehicles).

Louisiana

In response to the NFEA, the Louisiana Artificial Reef Initiative (LARI) combined the talents of university, State, Federal, and industry representatives to develop an artificial-reef program for the State of Louisiana. As a result, the Louisiana Fishing Enhancement Act (Act 100) became law in 1986. Subsequently, the Louisiana Artificial Reef Plan was written and contains the rational and guidelines for implementation and maintenance of the State artificial-reef program. The State plan is implemented under the leadership of the Louisiana Department of Wildlife and Fisheries. .

The LARI approved nine artificial-reef planning areas where artificial reefs can be sited (Kasprzak and Perret, 1996). Artificial-reef complexes are established within the planning areas on the basis of the best available information regarding bottom type, currents, bathymetry, and other factors affecting performance and productivity of the reefs. Retired oil and gas platforms are the primary materials that have been use within the Louisiana artificial-reef program. Military battle tanks have also been deployed offshore Louisiana for artificial reefs.

Mississippi

Mississippi's artificial-reef efforts began in the 1960's. A group consisting primarily of charter-boat operators and recreational fishermen obtained funding from their local coastal counties and constructed a car-body reef site in the early 1960's. In 1972, the Mississippi Marine Conservation Commission, the organizational predecessor of the current Mississippi Department of Marine Resources, acquired five surplus liberty ships for artificial reefs. This liberty-ship project was completed in 1978. The excess funds from the project and the reef permits were transferred to the Mississippi Gulf Fishing Banks, Inc., a private reef-building organization made-up of conservationists, charter-boat operators, and recreational fishermen.

Presently, Mississippi has 25 near-shore, low-profile fishing reefs and 9 offshore reefs. Most of the offshore sites are located within 16-23 km from shore. Artificial-reef materials used on these sites include liberty ships, rig quarters, tugboats, barges, boxcars, buses, dumpsters, concrete modules, tires, and Fish Aggregating Devices. All of Mississippi's reef sites have active reef permits and suitable material can be deployed at these sites, as they become available (Brainard, 1996).

Alabama

Alabama's artificial-reef efforts began in 1953. The first reef project resulted in placement of 250 automobile bodies in water depths of 20-30 m offshore Baldwin County. Alabama Department of Conservation and Natural Resources (ADCNR) is the responsible State agency for artificial-reef development in State and Federal waters. Alabama's most impressive and lasting contribution to artificial-reef activities is the acquisition and placement of five liberty ships in five locations in Alabama's offshore waters, which provide excellent offshore fishing opportunities for recreational fisherman. In 1986 and 1987, the ADCNR was granted by the U.S. Army Corps of Engineers (COE) two artificial-reef general-permit areas (Don Kelly North and Don Kelly South) offshore Baldwin County. In 1991, a third artificial-reef general-permit area (Hugh Swingle) was granted by the COE offshore Mobile County. In 1997, a proposal for extension of the three general-permit areas was requested by the ADCNR and permits were issued that year by the COE (Tatum, 1993). Alabama has used a large variety of materials (e.g. shell, concrete, automobile, vehicle tires, aircraft, railroad cars, steel and wooden vessels, and military battle tanks) for reefs with their artificial-reef program.

Florida

Florida's first permitted artificial-reef site was issued in 1918 (Pybas, 1991). A rapid proliferation of artificial-reef sites began in 1980. In the past 20 years, 309 reef sites were established in State and Federal waters off 33 Florida coastal counties on both the Gulf and Atlantic coasts. Almost 1,500 separate deployments of artificial-reef materials have been recorded within these permitted sites. Artificial reefs were built at water depths ranging from less than 3 m to greater than 200 m. For the past 20 years, Florida's artificial-reef program has been a cooperative effort of local governments and State agencies with additional input provided by non-governmental fishing and diving interests. The Florida Fish and Wildlife Conservation Commission, Division of Marine Fisheries, manages the State's artificial-reef program. The primary objective of the State's program has been to provide grants-in-aid to local coastal governments to develop artificial-fishing reefs in State and adjacent Federal waters to increase local sport-fishing resources and enhance sport-fishing opportunities (Dodrill and Horn, 1996; Maher, 1999). Florida has used a large variety of materials previously mentioned for reef within their artificial-reef program

Rigs-to-Reefs Development

Rigs-to-Reefs (RTR) is a catchy term for converting obsolete, nonproductive, offshore oil and gas platforms to designated artificial reefs (Dauterive, 2000). Offshore oil and gas platforms began functioning as artificial reefs in 1947 when Kerr-McGee completed the world's first commercially successful oil well in 5.6 m of water, 70 km south of Morgan City, Louisiana. Approximately 4,000 offshore oil and gas platforms exist on the Gulf of Mexico OCS beyond state territorial waters, with most (>90%) occurring offshore the States of Louisiana and Texas. Distribution of offshore platforms across the GOM is presented in Figure 9-5. Placed with the primary intent of producing oil and/or gas, offshore platforms also provide artificial substrate and marine habitat where natural hard-bottom habitat is at a minimum. Stanley (personal communication, 1998) calculated that the entire submerged portions of oil and gas platforms in the GOM provides some 12 km^2 of hard substrate. These platforms form the most extensive *de facto* artificial-reef systems in the world, providing some of the best habitat for reef-associated species.

The MMS regulations require that platforms be removed within one year after termination of the lease and the platform disposed onshore. Figure 9-6 provides the number of platforms installed (5,862) and removed (1,879) from 1942 through 1999. Between 1990-1999, the removal of platforms almost kept pace with the installation of platforms (Dauterive, 2000). A forecast of the offshore platforms on the Gulf OCS indicates a decline of about 29 percent in the number of platforms over the period 1999-2023 (Pulsipher et al., 2000). Disposal of obsolete offshore oil and gas platforms is not only a financial liability for the oil and gas industry but can be a loss of productive marine habitat (Kasprzak and Perret, 1996).

The use of obsolete oil and gas platforms for reefs has proven to be highly successful. Their availability, design profile, durability, and stability provide a number of advantages over the use of traditional artificial-reef materials. To capture this recyclable and valuable fish habitat, the States of Louisiana, Texas, and Mississippi in 1986, 1989, and 1999, respectively, passed enabling legislation and signed into law RTR plans for their respective States. Alabama and Florida have no RTR legislation. The distribution of RTR location across the GOM is presented in Figure 9-7.

The State laws set up a mechanism to transfer ownership and liability of the platform from oil and gas companies to the State when the platform ceases production and the lease is terminated. The company (donor) saves money by donating a platform to the State (recipient) for use as a reef rather than scrapping the platform onshore. The industry then donates 50 percent of the savings to the State to run the State's artificial-reef program. Since the inception of the RTR plans, more than 150 retired platforms have been donated and used for reefs offshore of the Gulf Coast States. Table 9-4 shows the RTR donations by State.

Texas Rigs-to-Reefs

The State of Texas passed enabling legislation (Texas Artificial Reef Act of 1989) formally recognizing the benefits of artificial reefs and RTR as a fishery development and management tool. At the end of 1999, Texas had 50 RTR platform donations within the State's artificial-reef program. Texas is the leader in using the partial removal method of removing platforms. This nonexplosive method of partial platform removal is the preferred method in support of artificial reefs because of the higher reef profile and the minimal trauma to and loss of platform-associated reef organisms. This method also generally results in more economic savings to the industry and monetary benefit to the State.

Louisiana Rigs-to-Reefs

In 1986, Louisiana passed enabling legislation (Louisiana Fishing Enhancement Act) for transfer and receipt of material for use as artificial reefs. The Act mandated preparation of the Louisiana Artificial Reef Plan. The Plan contains the rationale and guidelines for implementation and maintenance of the state's artificial reef program. The Louisiana Artificial Reef Council approved initially seven artificial-reef planning areas. Subsequently, two additional planning areas were added. These planning areas are strategically located along the Louisiana coast in various water depths and distances from shore for receipt of platform reefs and artificial reef materials. Figure 9-4 shows the location of Louisiana nine reef planning areas. Louisiana is also the leading state with 94 RTR platform donations within the State's artificial-reef program (Table 9-4).

Mississippi Rigs-to-Reefs

The MDMR has developed an artificial-reef plan for the State. The plan includes decommissioned platforms as an important artificial-reef material for deployment on Mississippi's approved artificial-reef sites. Because the continental shelf off of Mississippi has a very gentle slope and the water is shallow for a great distance from shore, the Mississippi RTR program is somewhat limited. Since water deep enough for RTR sites is far from shore, fishermen must travel great distances t reach the reefs. The State passed enabling legislation in 1999 allowing for the transfer of platform and platform liability along with industry cost saving for transfer of the platform to the State's artificial reef program. Platforms have been deployed for RTR at three locations offshore Mississippi.

Alabama Rigs-to-Reefs

Sections of a retired Marathon Oil Company platform were donated to the State of Alabama in 1983, and sunk by the Alabama Department of Conservation and Natural Resources some 60 miles offshore Alabama in 80 m of water (Tatum, 1993). In 2000, the State applied for and was permitted by the COE, to use a partially removed platform as an artificial reef in Main Pass Block 254.

Alabama is considering an RTR plan that will allow the State to accept 50 percent of the cost savings realized by the platform operator by not removing and transporting the platform to shore per MMS requirements.

Florida Rigs-to-Reefs

Obsolete oil and gas platforms have been placed as reefs at four locations on the OCS offshore Florida. In 1980, Exxon donated and placed a sub-sea production template offshore Apalachicola, Florida. In 1982, Tenneco donated and placed a platform's jackets and deck offshore Pensacola, Florida. In 1985, Tenneco again donated and placed two platform jackets offshore Miami, Florida. In 1993, Chevron donated a platform jacket and deck offshore Pensacola, Florida. The Florida Panhandle counties have expressed an interest in platforms as artificial reefs (Dodrill and Horn, 1996).

9.1.5. Existing OCS-Related Infrastructure

Offshore Infrastructure

The numbers below reflect offshore activities in the Gulf of Mexico OCS as of May 2001. All numbers presented are from an analysis of data contained in the MMS Technical Information Management System (TIMS), unless otherwise denoted.

Exploration and Delineation Wells (all wells ever drilled)

	Water Depth			
Planning Area	0-60 m	61-200 m	201-900 m	>900 m
Central	3,014	4,189	2,935	899
Western	459	1,328	722	303
Eastern	1	21	22	4
Total	3,474	5,538	3,679	1,206

Exploration and Delineation Wells (currently active wells)

	Water Depth			
Planning Area	0-60 m	61-200 m	201-900 m	>900 m
Central	871	1,036	745	350
Western	111	176	94	124
Eastern	1	1	0	1
Total	983	1,213	839	475

Development Wells (boreholes) (all wells ever drilled)

Planning Area	Water Depth 0-60 m	61-200 m	201-900 m	>900 m
Central	7,135	9,209	5,850	646
Western	381	1,409	1,171	172
Eastern	0	0	1	0
Total	7,516	10,618	7,022	818

Development Wells (boreholes) (currently active)

Planning Area	Water Depth 0-60 m	61-200 m	201-900 m	>900 m
Central	3,775	5,435	4,276	527
Western	232	821	895	143
Eastern	0	0	0	0
Total	4,007	6,256	5,171	670

Percentage of Development Wells that become Producing Wells

Planning Area	Water Depth 0-60 m	61-200 m	201-900 m	>900 m
Central	90.8%	93.7%	92.6%	94.7%
Western	93.9%	94.9%	95.9%	100.0%
Eastern	0.0%	0.0%	0.0%	0.0%
Total	91.0%	93.9%	93.3%	96.7%

Average Number of Days to Drill a Development Well

Planning Area	Water Depth 0-60 m	61-200 m	201-900 m	>900 m
Central	69	85	96	82
Western	90	120	116	114
Eastern	n/a	n/a	n/a	n/a
Total	70	89	99	87

"n/a" refers to "not applicable"

Average Life of a Producing Well (years)

Planning Area	Water Depth 0-60 m	61-200 m	201-900 m	>900 m
Central	16	11	7	n/a
Western	11	11	4	n/a
Eastern	n/a	n/a	n/a	n/a
Total	16	11	7	n/a

"n/a" refers to "not applicable"

Average Measured Depth of a Development Well (ft)

Planning Area	Water Depth 0-60 m	61-200 m	201-900 m	>900 m
Central	10,400	10,890	9,200	12,840
Western	11,260	9,880	9,520	13,990
Eastern	p	p	p	p
Total	10,440	10,760	9,250	13,080

"p" refers to "proprietary"

Number of Platforms by Platform Type

Platform Type	Central Planning Area	Western Planning Area	Eastern Planning Area	Total
Caisson	1,208	103	1	1,412
Compliant Towers	1	1	0	2
Fixed Leg	1,752	361	0	2,113
Mobile Production Units	1	0	0	1
Mini TLP's	2	0	0	2
SPARS	1	1	0	2
Subsea Manifolds	2	2	0	4
Subsea Templates	8	0	0	8
Tension Leg	6	0	0	6
Well Protectors	383	62	0	445

Gulf of Mexico Rig Utilization and Day Rates

Rig Type	Total Supply	Marketed Supply	Total Contracted	Fleet Utilization	Marketed Utilization	Day Rate Range ($ 000)
Jack-Ups	156	146	144	92.3%	98.6%	30-85
Semi-submersibles	42	35	34	81.0%	97.1%	42-130
Drillships	7	7	7	100.0%	100.0%	140-150
Submersibles	7	6	6	85.7%	100.0%	35-41
Platform Rigs	79	60	49	62.0%	81.7%	n/a

Source: One Offshore, 2001.

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APPENDIX 9.2

STATE COASTAL ZONE MANAGEMENT PROGRAMS

9.2. State Coastal Zone Management Programs

Each State's CZM program, federally approved by NOAA, is a comprehensive statement setting forth objectives, enforceable policies, and standards for public and private use of land and water resources and uses in that State's coastal zone. The program provides for direct State land and water use planning and regulations. The plan also includes a definition of what constitutes permissible land uses and water uses. Once a State's CZM program is Federally approved, Federal agencies must ensure that their actions are consistent to the maximum extent practicable with the enforceable polices of the approved program. State and Federal agencies work together on joint planning and permitting, which reduces the regulatory burden on the public (USDOC, NOAA, 1989). Federal agencies provide feedback to the States through each Section 312 evaluation conducted by NOAA.

To ensure conformance with State CZM program policies and local land use plans, the MMS prepares the appropriate consistency document for each proposed OCS lease sale. Local land use agencies also have the opportunity to comment directly to MMS at any time, as well as during formal public comments periods related to announcement of the Draft 5-Year OCS Leasing Program, Call for Information and Notice of Intent to Prepare an EIS, EIS scoping, public hearings on Draft EIS, and the Proposed Notice of Sale.

A State's approved CZM program may also provide for the State's review of OCS plans, permits, and license activities to determine whether they will be conducted in a manner consistent with the State's CZM program. This review authority is applicable to activities conducted in any area that has been leased under the OCSLA and that affect any land or water use or natural resource within the State's coastal zone (16 U.S.C. 1456(c)(3)(B)). Through the designated State CZM agency, local land use entities are provided numerous opportunities to comment on the OCS Program.

State of Texas Coastal Management Program

The Texas Coastal Management Program (TCMP)/Final EIS was published in August 1996. On December 23, 1996, the TCMP was approved by NOAA, and requirements therein were made operational as of January 10, 1997. The TCMP is based primarily on the Coastal Coordination Act (CCA) of 1991 (33 Tex. Nat. Res. Code Ann. Ch. 201, *et seq.*), as amended by HB 3226 (1995), which calls for the development of a comprehensive coastal program based on existing statutes and regulations. The CCA established the geographic scope of the program by identifying the program's inland, interstate, and seaward boundaries. The program's seaward boundary is the State's territorial seaward limit (3 leagues or 10.3 mi). The State's inland boundary is based on the State's Coastal Facilities Designation Line (CFDL). The CFDL was developed in response to the Oil Spill Act of 1990 and basically delineates those areas within which oil spills could affect coastal waters or resources. For the purposes of the TCMP, the CFDL has been modified to capture wetlands in upper reaches of tidal waters. The geographic scope also extends upstream 200 mi from the mouths of rivers draining into coastal bays and estuaries in order to manage water appropriations on those rivers. The program's boundaries encompass all or portions of 19 coastal counties (including Cameron, Willacy, Kenedy, Kleberg, Nueces, San Patricio, Aransas, Refugio, Calhoun, Victoria, Jackson, Matagorda, Brazoria, Galveston, Harris, Chambers, Liberty, Jefferson, and Orange Counties); roughly 8.9 million acres of land and water.

Within this coastal zone boundary, the scope of the TCMP's regulatory program is focused on the direct management of 14 generic "Areas of Particular Concern," called coastal natural resource areas (CNRA's). These CNRA's are associated with valuable coastal resources or vulnerable or unique coastal areas and include the following: waters of the open Gulf of Mexico; waters under tidal influence; submerged lands; coastal wetlands; seagrasses; tidal sand and mud flats; oyster reefs; hard substrate reefs; coastal barriers; coastal shore areas; Gulf beaches; critical dune areas; special hazard areas; critical erosion areas; coastal historic areas; and coastal preserves.

The State has designated the WPA as the geographical area in which Federal consistency shall apply outside of the coastal boundary. The TCMP also identifies Federal lands excluded from the State's coastal zone, such as Department of Defense Facilities.

Land and water uses subject to the program generally include the siting, construction, and maintenance of electric generating and transmission facilities; oil and gas exploration and production; and the siting, construction, and maintenance of residential, commercial, and industrial development on beaches, critical dune areas, shorelines, and within or adjacent to critical areas and other CNRA's. Associated activities also subject to the program include canal dredging; filling; placement of structures for shoreline access and shoreline protection; on-site sewage disposal, storm-water control, and waste management for local governments and municipalities; the siting, construction, and maintenance of public buildings and public works such as dams, reservoirs, flood control projects and associated activities; the siting, construction, and maintenance of roads, highways, bridges, causeways, airports, railroads, and nonenergy transmission lines and associated activities; certain agricultural and silvicultural activities; water impoundments and diversions; and the siting, construction, and maintenance of marinas, State-owned fishing cabins, artificial reefs, public recreational facilities, structures for shoreline access and shoreline protection, and boat ramps.

The TCMP is a networked program that will be implemented primarily through 8 State agencies, 18 local governments, and the Coastal Coordination Council. The program will rely primarily on direct State control of land and water uses, although local governments will implement State guidelines related to beach and dune management. Implementation and enforcement of the coastal policies is primarily the responsibility of the networked agencies and local governments through their existing statutes, regulatory programs, or other authorizations. Networked agencies include the General Land Office/School Land Board, Texas Natural Resource Conservation Commission, Railroad Commission, Texas Parks and Wildlife Department, Texas Transportation Commission, Texas Historical Commission, the Public Utility Commission, the Texas State Soil and Water Conservation Board, and the Texas Water Development Board. Similarly, 18 county and municipal governments, in those counties with barrier islands, are also networked entities with responsibilities for program implementation vis-a-vis beaches and dunes.

Local land uses and government entities are linked to the management of Texas CNRA's in the TCMP. Local governments are notified of relevant TCMP decisions, including those that may conflict with local land use plans or zoning ordinances. The Coastal Coordination Council includes a local government representative as a full-voting member. An additional local government representative can be added to the Council as a nonvoting member for special local matters under review. The Council will establish a permanent advisory committee to ensure effective communication for local governments with land use authority.

In 1994, MMS entered into a Memorandum of Understanding (MOU) with the Texas General Land Office to address similar mineral resource management responsibilities between the two entities and to encourage cooperative efforts and promote consistent regulatory practices. This MOU, which encompasses a broad range of issues and processes, outlines the responsibilities and cooperative efforts, including leasing and CZMA review processes, agreed to by the respective agencies. The MMS is developing coordination procedures with the State for submittal of offshore lease sale consistency determinations and plans of operation. Western Gulf Sale 168 was the first MMS Federal action subject to State consistency review. For plans of operation, the State has agreed that the information requirements of NTL No. 2000-G21 constitute the information needed for their consistency certification review. Effective January 10, 1997, all operators were required to submit to MMS certificates of consistency with the TCMP for proposed operations in the WPA. The MMS and the State of Texas are currently working to revise CZM consistency information for OCS plans, permits and licenses to conform to the revised CZM regulations that were effective January 8, 2001.

State of Louisiana Coastal Resources Program

The basis for Louisiana's coastal zone management program is the Louisiana Coastal Resources Program (LCRP) created by the State and Local Coastal Resources Management Act of 1978 (Louisiana Administrative Code, Vol. 17, Title 43, Chapter 7, Coastal Management, June 1990 revised). The Act puts into effect a set of State coastal policies and coastal use guidelines that apply to coastal land and water use decisionmaking. A number of existing State regulations are also incorporated into the program including those concerning oil and gas and other mineral operations; leasing of State lands for mineral operations and other purposes; hazardous waste and radioactive materials; management of wildlife, fish, other aquatic life, and oyster beds; endangered species; air and water quality; and the Louisiana Offshore Oil Port (LOOP).

The Act also authorized establishment of Special Management Areas. Included or planned to be included as Special Management Areas are LOOP and Marsh Island. For purposes of the CZMA, only that portion of LOOP within Louisiana's coastal zone is part of the Special Management Area. In April

1989, the Louisiana Legislature created the Wetlands Conservation and Restoration Authority and established a Wetlands Conservation and Restoration Trust Fund to underwrite restoration projects. The Legislature also reorganized part of the Louisiana Department of Natural Resources (LDNR) by creating the Office of Coastal Restoration and Management.

Local governments (parishes) may assume management of uses of local concern by developing a local coastal program consistent with the State CZM plan. The State of Louisiana has ten approved local coastal management programs (Calcasieu, Cameron, Jefferson, Lafourche, Orleans, St. Bernard, St. James, St. John the Baptist, Terrebonne, and St. Tammany Parishes). Nine others (Assumption, Iberia, Livingston, Plaquemines, St. Charles, St. Martin, St. Mary, Tangipahoa, and Vermilion Parishes) have not formally been approved by NOAA. The parish police jury often serves as the permitting agency for projects limited to local concern. Parish-level programs function in an advisory capacity to Louisiana's CZM agency, the Coastal Management Division.

Appendix C2 of the LCRP outlines the rules and procedures for the State's local coastal management programs. Under the LCRP, parishes are authorized, though not required, to develop local coastal management programs. Approval of these programs gives parishes greater authority in regulating coastal development projects that entail uses of local concern. Priorities, objectives, and policies of local land use plans must be consistent with the policies and objectives of Act 361 and the State guidelines, except for a variance adopted in Section IV.D. of Appendix C2 of the LCRP. The Secretaries of the Departments of Natural Resources, and Wildlife and Fisheries may jointly rule on an inconsistent local program based on local environmental conditions or user practices. State and Federal agencies review parish programs before they are adopted.

The coastal use guidelines are based on seven general policies. State concerns that could be relevant to an OCS lease sale and its possible direct effects or associated facilities and nonassociated facilities are (a) any dredge and fill activity that intersects more than one water body, (b) projects involving the use of State-owned lands or water bottoms, (c) national interest projects, (d) pipelines, and (e) energy facility siting and development. Other coastal activities of concern that could be relevant to a lease sale include wetland loss due to channel erosion from OCS traffic; activities near reefs and topographic highs; activities that might affect endangered, threatened, or commercially valuable wildlife; and potential socioeconomic impacts due to offshore development.

Effective August 1993, the DNR Coastal Management Division requires that any entity applying for permits to conduct activities along the coast must notify the landowner of the proposed activity. An affidavit must also accompany any permit application. Through this regulation, the State will strive to minimize coastal zone conflicts.

The MMS and the State of Louisiana are currently working to revise CZM consistency information for OCS plans, permits, and licenses to conform to the revised CZM regulations that were effective January 8, 2001.

State of Mississippi Coastal Program

The Mississippi Coastal Program (MCP) is administered by the Mississippi Department of Marine Resources. The MCP is built around 10 enforceable goals that promote comprehensive management of coastal resources and encourage a balance between environmental protection/preservation and development in the coastal zone. The primary coastal management statute is the Coastal Wetlands Protection Law. Other major features of the MCP include statutes related to fisheries, air and water pollution control, surface and groundwater, cultural resources, and the disposal of solid waste in marine waters. The Department of Marine Resources, the Department of Environmental Quality, and the Department of Archives and History are identified collectively as the "coastal program agencies." Mississippi manages coastal resources by regulation and by promoting activities that use resources in compliance with the MCP. The State developed a coastal wetlands use plan, which includes designated use districts in coastal wetlands and Special Management Area Plans that steer development away from fragile coastal resources and help to resolve user conflicts.

For the purposes of the coastal program, the coastal zone encompasses the three coastal counties of Hancock, Harrison, and Jackson and all coastal waters. The Mississippi coast has 594 km of shoreline, including the coastlines of offshore barrier islands (Cat, Ship, Horn, and Petit Bois Islands). According to NOAA, there are no approved local coastal management plans for the State of Mississippi. The Southern

Mississippi Planning and Development District serves in an advisory capacity to the State coastal agencies.

The MMS and the State of Mississippi are currently working to revise CZM consistency information for OCS plans, permits, and licenses to conform to the revised CZM regulations that were effective January 8, 2001.

State of Alabama Coastal Area Management Program

The Alabama Coastal Area Act (ACAA) provides statutory authority to review all coastal resource uses and activities that have a direct and significant effect on the coastal area. The Alabama Department of Conservation and Natural Resources (ADCNR) Coastal Programs Office, the lead coastal management agency, is responsible for the management of the State's coastal resources through the Alabama Coastal Area Management Plan (ACAMP). The ADCNR is responsible for the overall management of the program including fiscal and grants management and public education and information. The department also provides planning and technical assistance to local governments and financial assistance to research facilities and units of local government when appropriate.

The Alabama Department of Environmental Management (ADEM) is responsible for coastal area permitting, regulatory and enforcement functions. All programs of ADCNR Coastal Programs that require environmental permits or enforcement functions are carried out by the ADEM. The ADEM has the responsibility of all permit, enforcement, regulatory, and monitoring activities, and the adoption of rules and regulations to carry out the ACAMP. The ADEM must identify specific uses or activities that require a State permit to be consistent with the coastal policies noted above and the more detailed rules and regulations promulgated as part of the ACAMP. Under the ACAA, State agency activities must be consistent with ACAMP policies and ADEM findings. Further, ADEM must make a direct permit-type review for uses that are not otherwise regulated at the State level. The ADEM also has authority to review local government actions and to assure that local governments do not unreasonably restrict or exclude uses of regional benefit. Ports and major energy facilities are designated as uses of regional benefit.

Local governments have the option to participate in the ACAMP by developing local codes, regulations, rules, ordinances, plans, maps, or any other device used to issue permits or licenses. If these instruments are certified to be consistent with ACAMP, ADEM may allow the local government to administer them by delegating its permit authority, thereby eliminating the need for ADEM's case-by-case review.

According to NOAA, there are no local coastal management plans approved for the State of Alabama. However, local authorities such as municipal and county planning commissions serve in an advisory capacity to local government and, in certain instances, have authority to make development decisions that impact the coastal area. The South Alabama Regional Planning Commission provides ongoing technical assistance to ADCNR for Federal consistency, clearinghouse review, and public participation procedures.

Uses subject to the Alabama's CZM program are divided into regulated and nonregulated categories. Regulated uses are those that have a direct and significant impact on the coastal areas. These uses either require a State permit or are required by Federal law to be consistent with the management program. Uses that require a State permit must receive a certificate of compliance. Nonregulated uses are those activities that have a direct and significant impact on the coastal areas that do not require a State permit or Federal consistency certification. Nonregulated uses must be consistent with ACAMP and require local permits to be administered by ADEM.

The MMS and the State of Alabama are currently working to revise CZM consistency information for OCS plans, permits, and licenses to conform to the revised CZM regulations that were effective January 8, 2001.

Reference

U.S. Dept. of Commerce. 1989. Coastal zone management: a Federal-State partnership; the management of coastal and marine resources. CZM Information Exchange. January 1989.

APPENDIX 9.3

BIOLOGICAL OPINIONS AND ESSENTIAL FISH HABITAT CONSULTATION

Biological Opinions

BIOLOGICAL OPINIONS

As required by Section 7 of the Endangered Species Act, MMS requested a formal consultation with NOAA Fisheries on April 17, 2002, and with FWS on April 15, 2002. These consultations are to ensure that activities in the OCS under MMS jurisdiction do not jeopardize the continued existence of threatened or endangered species and/or result in adverse modification or destruction of their critical habitat. The MMS receives the results of each consultation in a Biological Opinion (BO). You may obtain copies of the final BO's by contacting the Minerals Management Service, Gulf of Mexico OCS Region, Public Information Office (MS 5034), 1201 Elmwood Park Boulevard, Room 114, New Orleans, Louisiana 70123-2394 (1-800-200-GULF) or by emailing a request to environment@mms.gov.

ESSENTIAL FISH HABITAT CONSULTATION

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southeast Regional Office
9721 Executive Center Drive N.
St. Petersburg, Florida 33702

April 26, 2002

Mr. Chris C. Oynes
Regional Director
Minerals Management Service
Gulf of Mexico OCS Region
1201 Elmwood Park Boulevard
New Orleans, Louisiana 70123

Dear Mr. Oynes:

The National Marine Fisheries Service (NMFS) has received the Minerals Management Service (MMS) letter of March 29, 2002, initiating Essential Fish Habitat (EFH) programmatic consultation for activities associated with Gulf of Mexico (GOM) Central Planning Area (CPA) and Western Planning Area (WPA) Lease Sales included in the 2002 to 2007, 5-Year Program. In addition, project-specific EFH consultation was requested for Lease Sale 184. The EFH programmatic consultation request was made pursuant to the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) and its implementing regulations [50 CFR 600.920(j)]. Consultation for Lease Sale 184 is consistent with the procedures specified in our interagency findings agreement of March 17, 2000.

The draft environmental impact statement (DEIS) for the 2002 to 2007 lease sales contains detailed descriptions of fishery resources, sensitive coastal environments, sensitive offshore resources, and habitats designated as EFH and Habitat Areas of Particular Concern by the Gulf of Mexico Fishery Management Council and NMFS. Consistent with the requirements of the EFH regulations and our interagency findings, the environmental assessment (EA) for Lease Sale 184 includes similar information, modified as appropriate to address the specific location and timing of the sale. The NMFS finds the EFH assessments contained in each document to be a comprehensive evaluation of potential adverse impacts associated with the two actions. The proposed actions are adequately described and potential impacts to EFH and associated fishery resources are thoroughly addressed. Mitigation measures addressed (i.e., existing environmental stipulations and additional EFH conservation recommendations from the 1999 programmatic consultation agreement) are those developed and implemented through an analytical process associated with past lease sales, MMS-funded research, and interagency coordination activities. The assessments contained in the EA and DEIS fully meet the requirements specified in the EFH regulations at 50 CFR 600.920(e).

In response to the GOM OCS Region's request that NMFS evaluate potential petroleum exploration and production impacts on EFH and Federally managed fisheries through programmatic and lease sale-specific consultations, we offer the following:

EFH Conservation Recommendations

Programmatic Consultation - 2002-2007
In its analysis of the lease sales included in the 5-year program, MMS discusses the 10 EFH conservation measures cooperatively developed in 1999 to minimize and avoid EFH impacts related to exploration and development activities in the CPA and WPA. Among these measures, the MMS routinely includes the following as potential mitigation measures:

1. Environmental stipulations for the protection of live bottom (pinnacle trend) resources, topographic features, and chemosynthetic communities are incorporated, as appropriate, in leases and approval documents prepared by the GOM OCS Region.

2. The Flower Garden Banks are provided added protection, under the topographic features stipulation, by establishing expanded zones of no activity and required shunting.

3. An oil spill response plan is required of all owners and operators of oil handling, storage, or transportation facilities located wholly or partly within Federal waters.

4. Pursuant to existing regulations, lessees are responsible for the control and removal of pollution to avoid risks to EFH and associated fisheries.

The NMFS endorses the implementation of these resource protection measures in future decision documents for lease sales and adopts these conditions as our EFH conservation recommendations for the 2002-2007 lease sales. If any changes are made to MMS programs or these stipulations, such that effects on EFH are potentially changed, MMS shall notify NMFS Southeast Region to allow our agencies to discuss whether this programmatic consultation should be revised. Should NMFS receive new or additional information that may affect EFH conservation recommendations, NMFS will consider whether to request additional consultation with MMS and/or provide additional EFH conservation recommendations. At intervals corresponding to the development of the five-year lease sale planning documents, the MMS Gulf of Mexico OCS Region and the NMFS Southeast Region will review these programmatic EFH conservation recommendations and determine whether they should be revised to account for any new information or new technology.

Lease Sale 184
The NMFS has no EFH conservation recommendations to offer with respect to Lease Sale 184. Specific, post-sale development activities remain subject to the provisions of our 1999 Programmatic Consultation agreement. We continue to believe that those previously agreed upon conservation recommendations concerning petroleum exploration and production would be sufficient to ensure that appropriate measures are taken to protect and conserve EFH in the central and western Gulf of Mexico.

As required by Section 305(b)(4)(B) of the Magnuson-Stevens Act, MMS must respond in writing within 30 days of receiving EFH conservation recommendations. MMS must include in their response the acceptability of the NMFS recommended measures to avoid, minimize, and mitigate adverse impacts to EFH from activities described in the 5-year program. If MMS's response is inconsistent with NMFS's EFH conservation recommendations, MMS must explain its reasons for not following the recommendations, including the scientific justification for any disagreements with NMFS over the anticipated effects of the proposed actions and the measures needed to avoid, minimize, mitigate, and offset such effects. If you are unable to substantively respond within 30 days, an interim response is acceptable. If an interim response is provided, your final response to our recommendations should be provided at least 10 days prior to signing a record of decision, finding of no significant impact, or similar action to complete your decision making process.

Thank you for this review opportunity. If MMS accepts our EFH conservation recommendations, no further EFH consultation is required, except in cases where the need for coordination on post-sale production and exploration activities has been specified in our 1999 Programmatic Consultation agreement.

Sincerely,

Andreas Mager, Jr.
Assistant Regional Administrator
Habitat Conservation Division